

SOURCE INVENTORY

CATEGORIES # 344 - 356

SHIPS

1999 EMISSIONS

Introduction

Emissions reported in these categories are from combustion of fuel from engines of commercial vessels arriving and departing the San Francisco Bay Area. The ship's main engine (steam or diesel) provides power for its movement, and auxiliary engines supply power to electrical systems, refrigeration and heating systems, pumps, etc. The engines are categorized as either a steamship using boiler-produced steam, or as a motorship propelled by an internal combustion engine. It was assumed that, for the most part, 90% of the ship traffic within the District are from motorships and 10% are from steamships ("vehicle carriers" and "others" are assumed to be all motorships).

The Maneuvering mode (Cat. #344-347) accounts for combustion emissions from ships moving within the berths, in and out of ports, or anchorage. Emissions from tugboat assistance (Cat. #348) were calculated separately and based on guiding a ship in and out of a port.

The Berthing (Hotelling) mode (Cat. #349-352) includes combustion emissions while a ship is stationary at a berth or at anchor within the breakwater. These may include emissions from the ship's main power system operating at reduced output, or auxiliary boilers and/or diesel motor/generators used to produce power to operate lighting, heating, cargo booms, etc.

In-Transit (Cruising) mode (Cat. #353-356) considers ship combustion emissions at rated cruising speed entering the District area, from approximately 3 miles west of Golden Gate Bridge, and through the major sea lanes in the San Francisco and San Pablo Bays.

Vessels may change berths once at port, or may travel to several different ports once inside the Bay. This is known as shifting. It was estimated shifting increased the maneuvering, berthing, and in-transit emissions by 20%.

Methodology

Ship traffic and type for 1999 were obtained from the San Francisco Marine Exchange. The data was expanded into different types of ships for each of the American and foreign steamships (SS) and motorships (MS). Ship types include Breakbulk, Bulk Carrier,

Chemical Tanker, Liquid Gas Carrier, Tanker, Container (full and part), Passenger, Roll-on/Roll-off, Vehicle Carriers, and Others.

The above ship types were allocated to the different ports in the Bay Area. For example, passenger ships exclusively call the Port of San Francisco; tanker vessels were assumed to call at the marine terminals of the major petroleum refineries in the Bay Area; the Port of Oakland receives (for the most part) containerships; etc. Within a particular ship type, the number of ships calling a port was proportioned to the representative cargo attributed to the ports as found in the 1999 US Army Corps of Engineers, Waterborne Commerce of the US. The average horsepower rating for the various ship types was calculated from the 1996 Acurex Report, "Marine Vessel Emissions Inventory and Control Strategies". The exception was the Port of Oakland providing horsepower ratings for their various containership sizes.

The following were the assumptions used for the different modes of transit (maneuvering, berthing and in-transit):

Maneuvering Mode

- * The time spent in maneuvering (see Table 1) during half-speed and slow speed at the various Bay Area ports were taken from the Booze, Allen, & Hamilton report, "Inventory of Air Pollutant Emissions from Marine Vessels", March 1991.
- * Fuel usage rates were 0.05 gal/hp-hr for motorships and 0.072 gal/hp-hr for steamships. Load factors for motorships (used in fuel usage calculations) were 0.4 at half-speed and 0.2 at slow speed. Load factors for steamships were 0.46 at half speed and 0.4 at slow speed.
- * Emission factors (see Table 2) for the various ship types were taken from the 1996 Acurex Report.

Berthing (Hotelling) Mode

- * The time spent in the berthing, or hotelling, mode (see Table 3) for the various ship types were taken from the 1996 Acurex Report. The exception to this was the Port of Oakland that provided berthing times for their various size containerships.
- * Fuel usage for motorships was based on production of 500 kilowatts of electricity from an auxiliary generator at 50% load; fuel usage for steamship generators was based on 0.072 gal/hp-hr at 20% load.
- * Emission factors for motorship generators (see Table 4) were based on a 1989 ship emission report from TRC (for Nox, Sox, and CO) and AP-42 Volume II, Table II - 3.4 (for PM and TOG). Emission factors for steamship generators (see Table 4) were based on the 1991 Booze, Allen, & Hamilton report mentioned above.

In-Transit (Cruising) Mode

- * In-transit times (see Table 1) to the various Bay Area ports were calculated from values found in the 1991 Booze, Allen, & Hamilton report, noting the 3 miles point outside the Golden Gate was used as the reference point.
- * The average cruising speed was 12 miles per hour.
- * Fuel usage rates were the same as in the maneuvering mode, namely 0.05 gal/hp-hr for motorships and 0.072 gal/hp-hr for steamships. Load factors for both motorships and steamships in this mode were 0.8.
- * Emission factors (see Table 5) for the different types of ships were taken from the 1996 Acurex report.

Tug Boats

- * Emission factors (ARB, 1984) were based on two 4,300 horsepower tugs operating 1 hour at half speed and 1/2 hour at slow speed (see Table 6); the units are in lbs./ship visit.

(Note: For those vessels traveling to the Ports of Sacramento and Stockton, the in-transit and maneuvering emissions that occur in the District's jurisdiction are also included in this inventory.)

Maneuvering, berthing, and in-transit emissions are calculated by multiplying the fuel usage (mgal) by the appropriate emission factor (lbs./mgal). Fuel usage values for maneuvering and in-transit in motorships and steamships were calculated by multiplying the following: horsepower rating of the vessel, load factor on the engines, fuel usage rate, and the duration time for maneuvering or in-transit operations. Fuel usage values for motorship berthing were based on 500 kilowatts of electricity generated from an auxiliary generator at 50% load. Fuel usage values for berthing in steamships was calculated in similar manner to the in-transit or maneuvering mode.

Monthly Variation

Monthly distribution was estimated based on the ships' traffic for each month as reported by the San Francisco Marine Exchange.

County Distribution

For maneuvering and in-transit categories, county fractions are not based on actual port location, but rather where the emissions activity occurred during the particular mode of operation of the vessel. For example, during the maneuvering or in-transit mode, vessels may pass through several counties on their way to and from port. Berthing and tugboat assistance operations occur at port, and therefore, county fractions here are based on the port's relevant activity.

TRENDS

History

Prior to 1999, growth was based on ship traffic provided by the Marine Exchange. District Regulation 6 regarding particulate matter and visible emissions are applicable to ships while berthing and has contributed in the improvement of air quality in the last decades.

Growth

Ship emission projections to the year 2030 were estimated to be at 2% growth per year. The Port of Oakland, the busiest port in the Bay Area handling primarily containerships, is proposing an expansion of their facilities to handle the predicted shift to larger vessels. In addition to having more cargo transferred per ship visit, emissions per ship visit would increase because of larger engines and increased time at port.

Table 1--Time in In-Transit and Maneuvering Modes*

Port	In-Transit (Hours)	Maneuvering	
		40% Load (Hours)	20% Load (Hours)
San Francisco	1.83	0.40	0.40
Oakland/Alameda	1.70	0.80	1.20
Redwood City	3.33	4.00	1.20
Richmond	1.67	1.20	1.20
Benicia/Martinez	3.83	6.00	0.80
Pittsburg/Antioch	3.83	8.00	0.40
San Pablo Bay	3.83	1.20	0.40
Concord NWS	3.83	7.00	0.80

*Times reflect both in and out of ports

Table 2 --Maneuvering Emission Factors

Shiptype	Propulsion Type	Maneuvering Emission Factors (lbs./Mgal)				
		PM	TOG	NOx	SOx	CO
Vehicle Carrier	Motorships	57	23	587	363	71
Bulk Carriers* (incl. Breakbulk & Roll-on/Roll-off Vessels)	Motorships	57	18	639	363	58
	Steamships	20	0.7	56	363	3.5
Containership	Motorships	57	19	643	363	57
	Steamships	20	0.7	56	363	3.5
Tankers (incl. Chemical & Liquid Gas Carrier, etc.)	Motorships	57	19	639	363	58
	Steamships	20	0.7	56	363	3.5
Other (assumed a General Cargo)	Motorships	57	22	603	363	67

* Motorship NOx and CO emission factors were a composite between the values of Bulk Carrier and Roll-on/Roll-off Vessels as found in the 1996 Acurex Report.

Table 3--Berthing Times for Various Vessels

Shiptype	Berthing Time (Hours)
Passenger	11
Vehicle	24
Tanker	58
Bulk Carrier, Breakbulk, and Roll On/Roll-Off	51.5
Other (General Cargo)	46.2

* Berthing time combined the 3 times proportionally

Table 4--Berthing Emission Factors

Propulsion Type	Berthing Emission Factors (lbs./Mgal)				
	PM	TOG	NOx	SOx	CO
Motorships	17	81.9	451.5	216.1	55.8
Steamships	15	3	22.2	71	4

Table 5 --In-Transit Emission Factors

Shiptype	Propulsion Type	In-Transit Emission Factors (lbs./Mgal)				
		PM	TOG	NOx	SOx	CO
Vehicle Carrier	Motorships	57	18	587	363	18
Bulk Carriers* (incl. Breakbulk & Roll-on/Roll-off Vessels)	Motorships	57	18	639	363	55
	Steamships	57	2	64	363	7
Containership	Motorships	57	18	643	363	55
	Steamships	57	2	64	363	7
Tankers (incl. Chemical & Liquid Gas Carrier, etc.)	Motorships	57	18	639	363	55
	Steamships	57	2	64	363	7
Other (assumed a General Cargo)	Motorships	57	18	603	363	55

* Motorship NOx emission factor was a composite between the values of Bulk Carrier and Roll-on/Roll-off Vessels as found in the 1996 Acurex Report.

Table 6--Tug Boat Emission Factors

Vessel Type	Tug Boat Emission Factors (lbs./ship visit)				
	PM	TOG	NOx	SOx	CO
Tug Boat	3.6	5	44.2	3.4	7.6